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Assessment of the CO2 capture potential from irreplaceable industrial sources

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Assessment of the CO_2 capture potential from irreplaceable industrial sources

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Engineering Conferences International

CO_2 Summit II: Technologies and Opportunities
April 10-14, 2016 Santa Ana Pueblo, NM, USA

Clean Energy Conversions Lab

cec-lab.stanford.edu

Mission Statement:

To design and understand trace metal and carbon dioxide transformation and/or capture on surfaces to prevent their release into the atmosphere.

Theory/Computation

- **DFT: Membranes**
- **GCMC: Solid Sorbents**
- **GIS: Source/Sink**

NSF

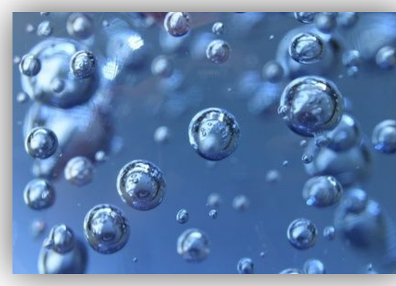
EPRI

GCEP
Global Climate & Energy Project
STANFORD UNIVERSITY

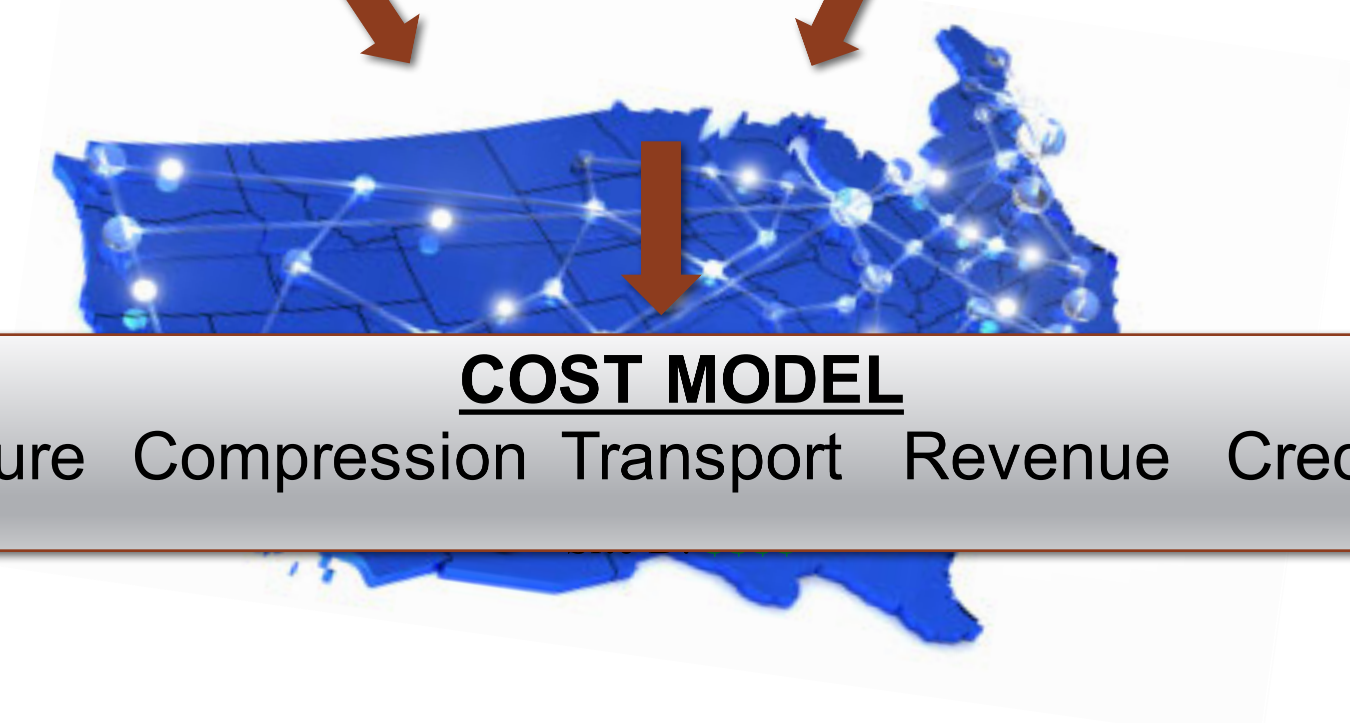
Chevron

Motivation – Phase II

Industrial
Sources
(Output)



Utilization
Opportunities
(Demand)



COST MODEL

Capture Compression Transport Revenue Credit

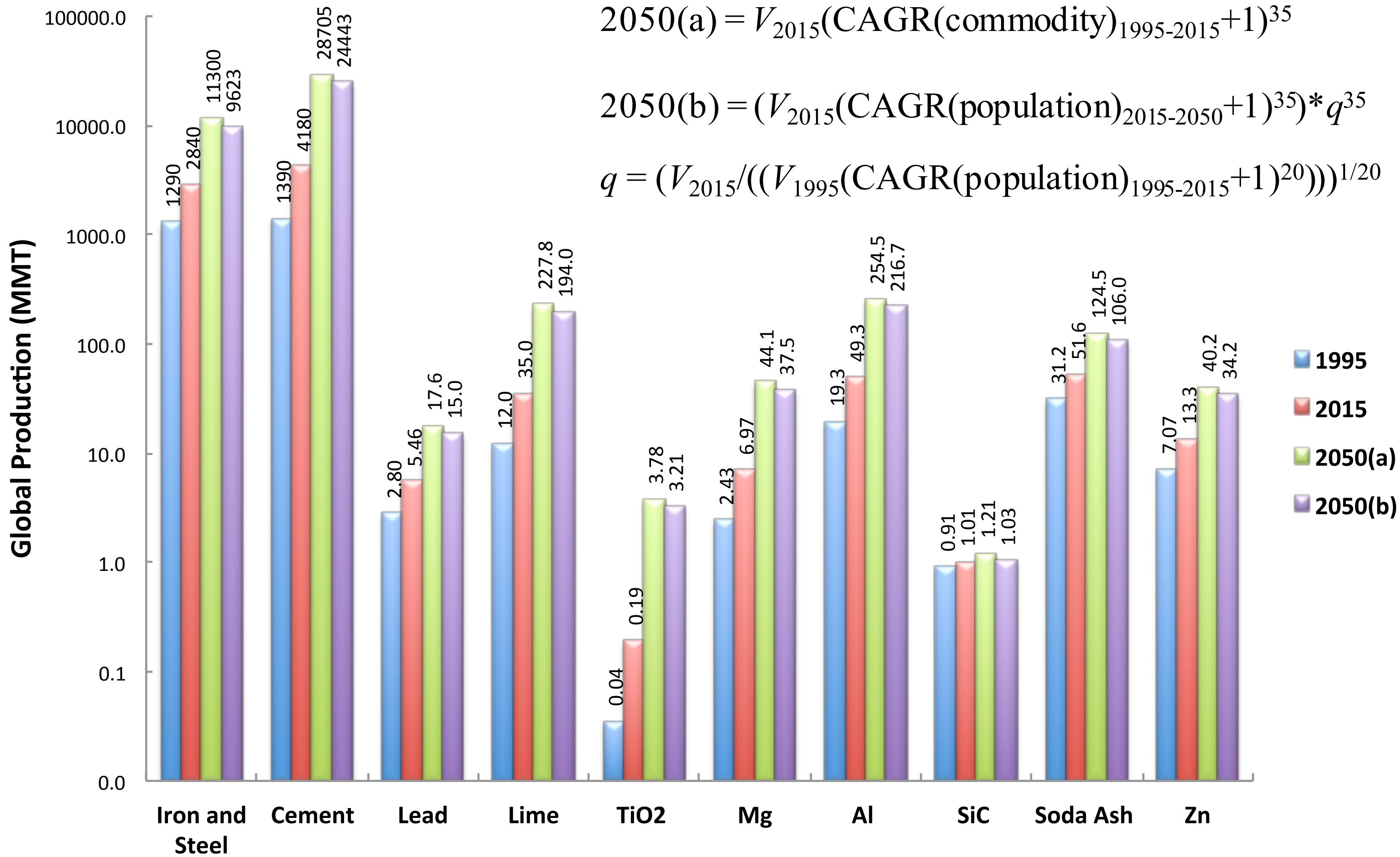
Irreplaceable Industrial Processes (IIP)

1. Must produce CO_2 as a reactionary byproduct
2. Product is "essential"

$$2050(a) = V_{2015}(CAGR(commodity)_{1995\text{-}2015}+1)^{35}$$

$$2050(b) = (V_{2015}(CAGR(population)_{2015\text{-}2050}+1)^{35})*q^{35}$$

$$q = (V_{2015}/((V_{1995}(CAGR(population)_{1995\text{-}2015}+1)^{20})))^{1/20}$$



Source: US Geological Survey, Mineral Commodity Summaries

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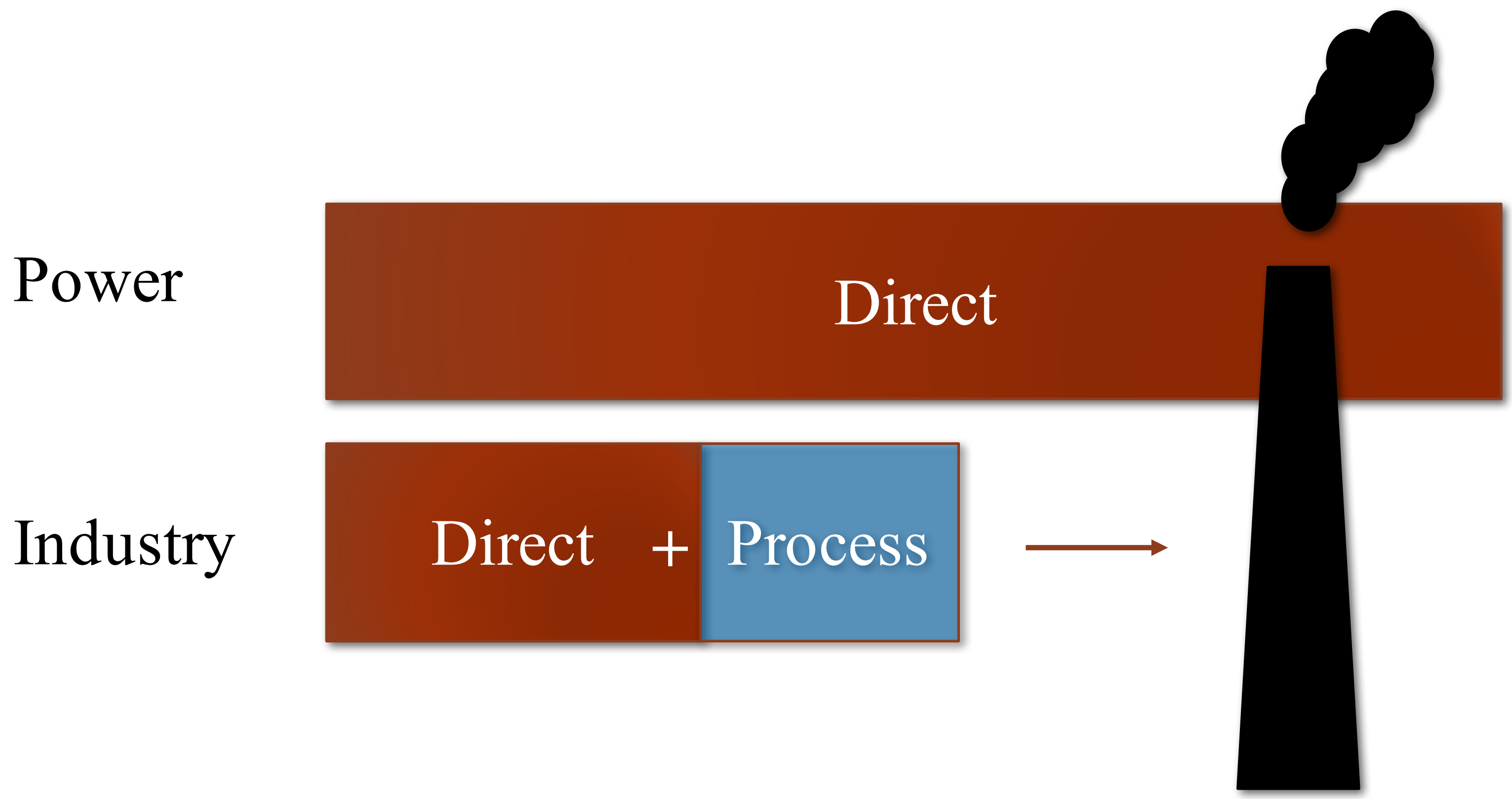
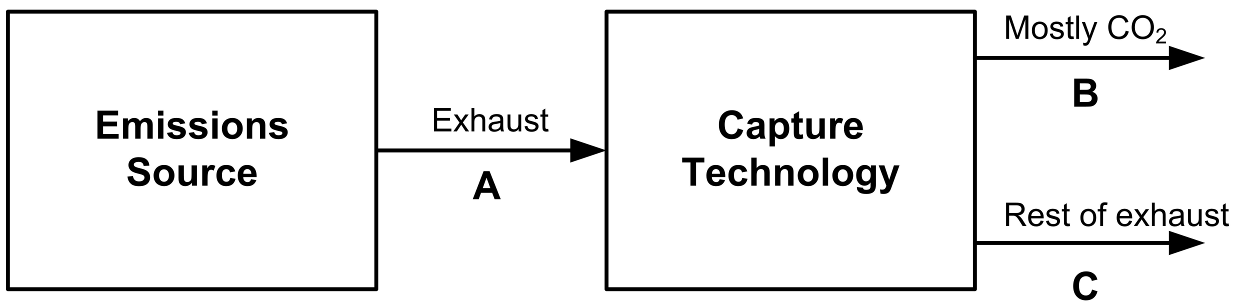
Irreplaceable Industrial Processes (IIP)

1. Must produce CO_2 as a reactionary byproduct
2. Product is “essential”
3. There exists no *reasonable carbon-free route to product or analogous product



Source: US Geological Survey, Mineral Commodity Summaries

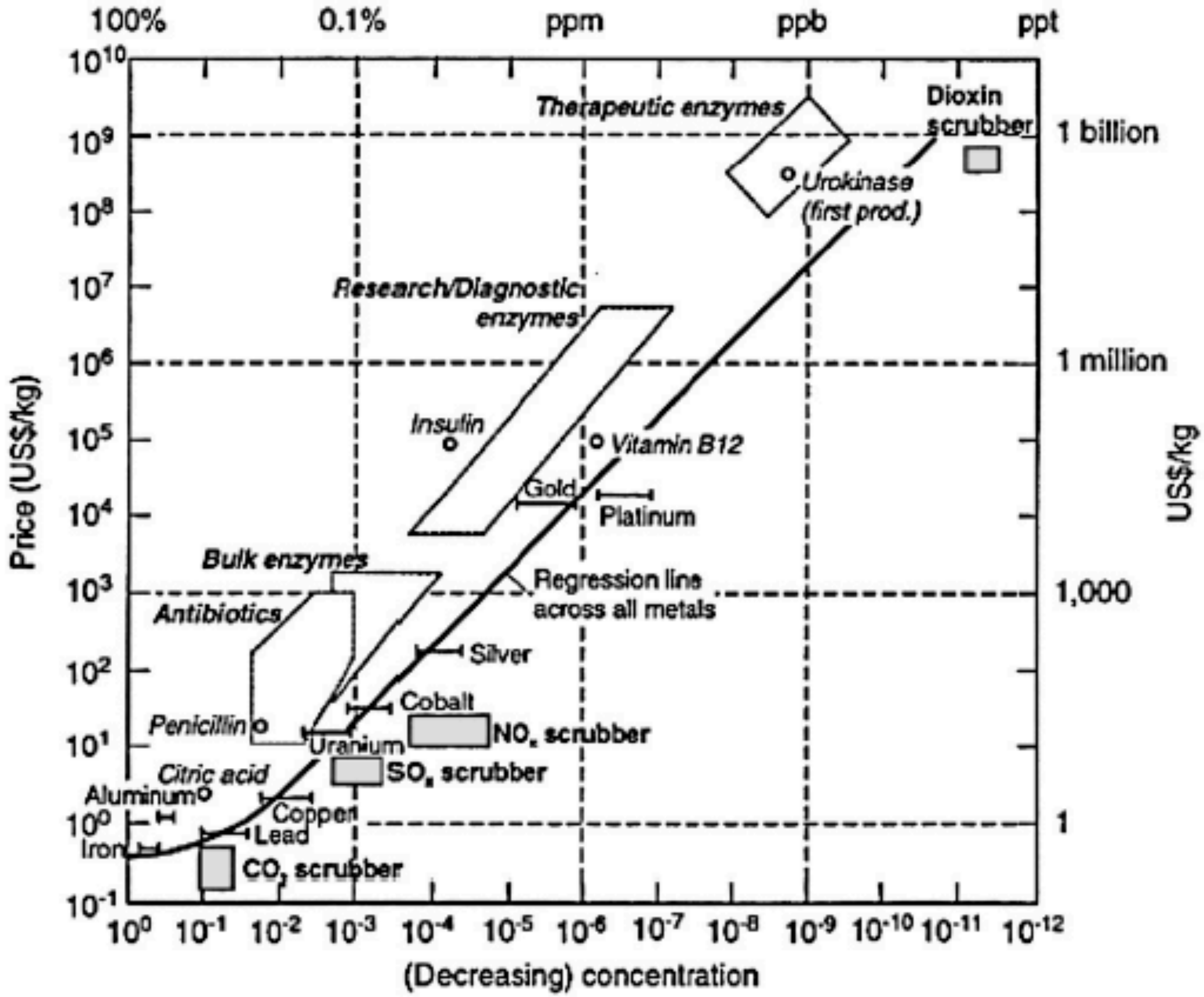
Minimum Work - Separations



$$W_{\min} = RT\left[n_B^{CO_2}\ln(y_B^{CO_2}) + n_B^{B-CO_2}\ln(y_B^{B-CO_2})\right] + RT\left[n_C^{CO_2}\ln(y_C^{CO_2}) + n_C^{C-CO_2}\ln(y_C^{C-CO_2})\right]$$
$$-RT\left[n_A^{CO_2}\ln(y_A^{CO_2}) + n_A^{A-CO_2}\ln(y_A^{A-CO_2})\right]$$

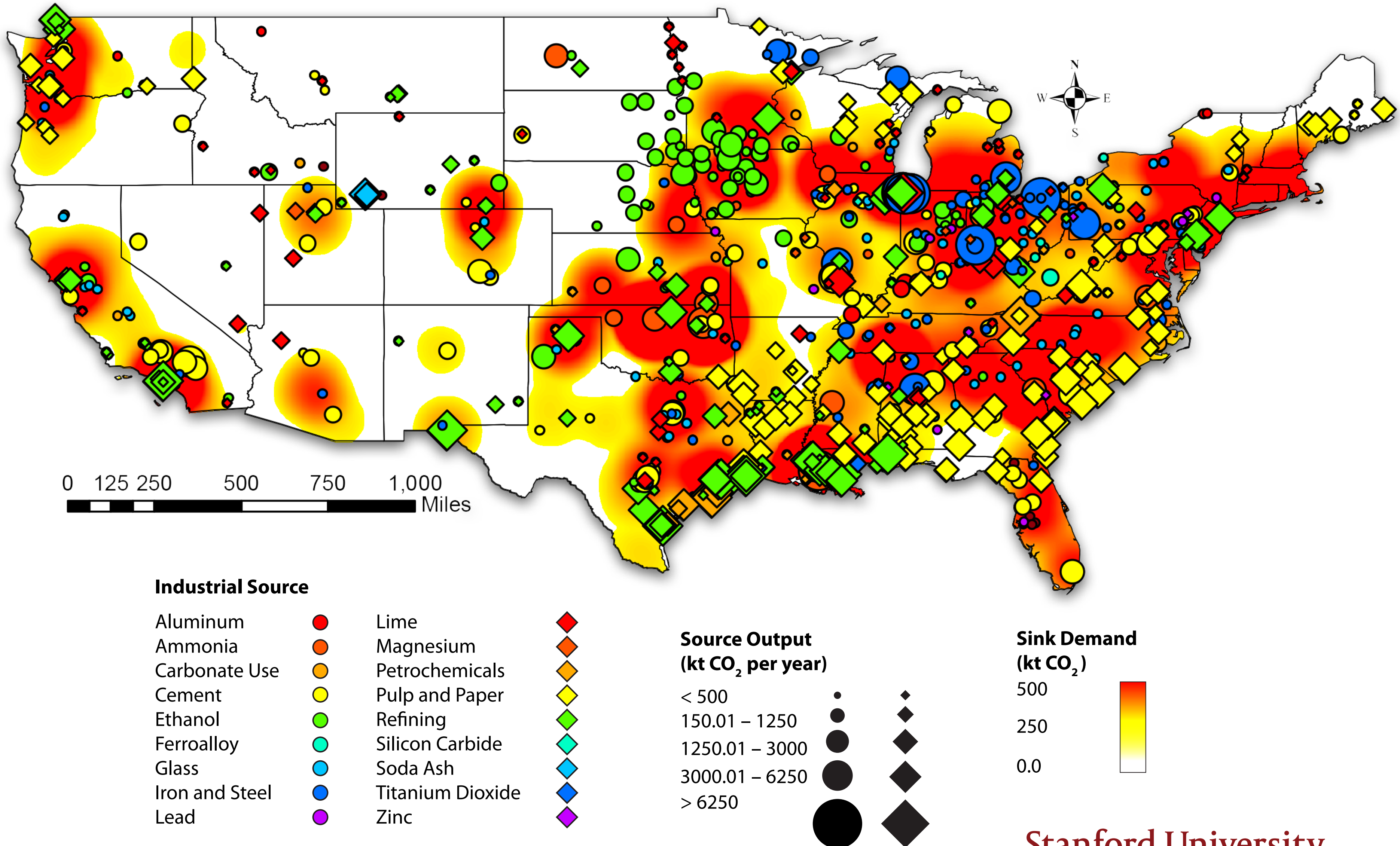
Wilcox, Carbon Capture, Springer, 2012

Sherwood Cost Estimation



Grübler A (1998) Technology and Global Change (Cambridge Univ Press, Cambridge, UK).

U.S. Source Distribution



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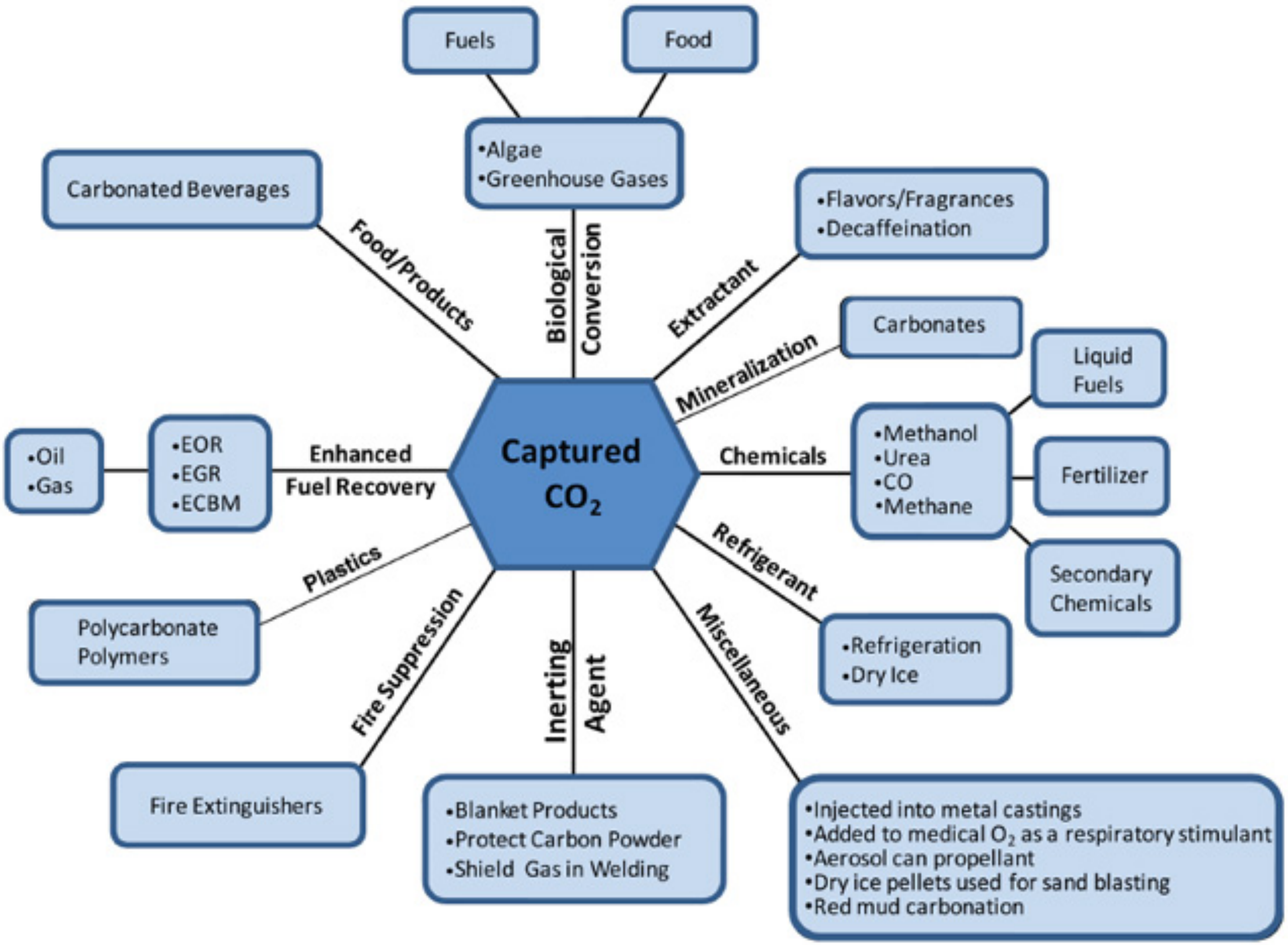
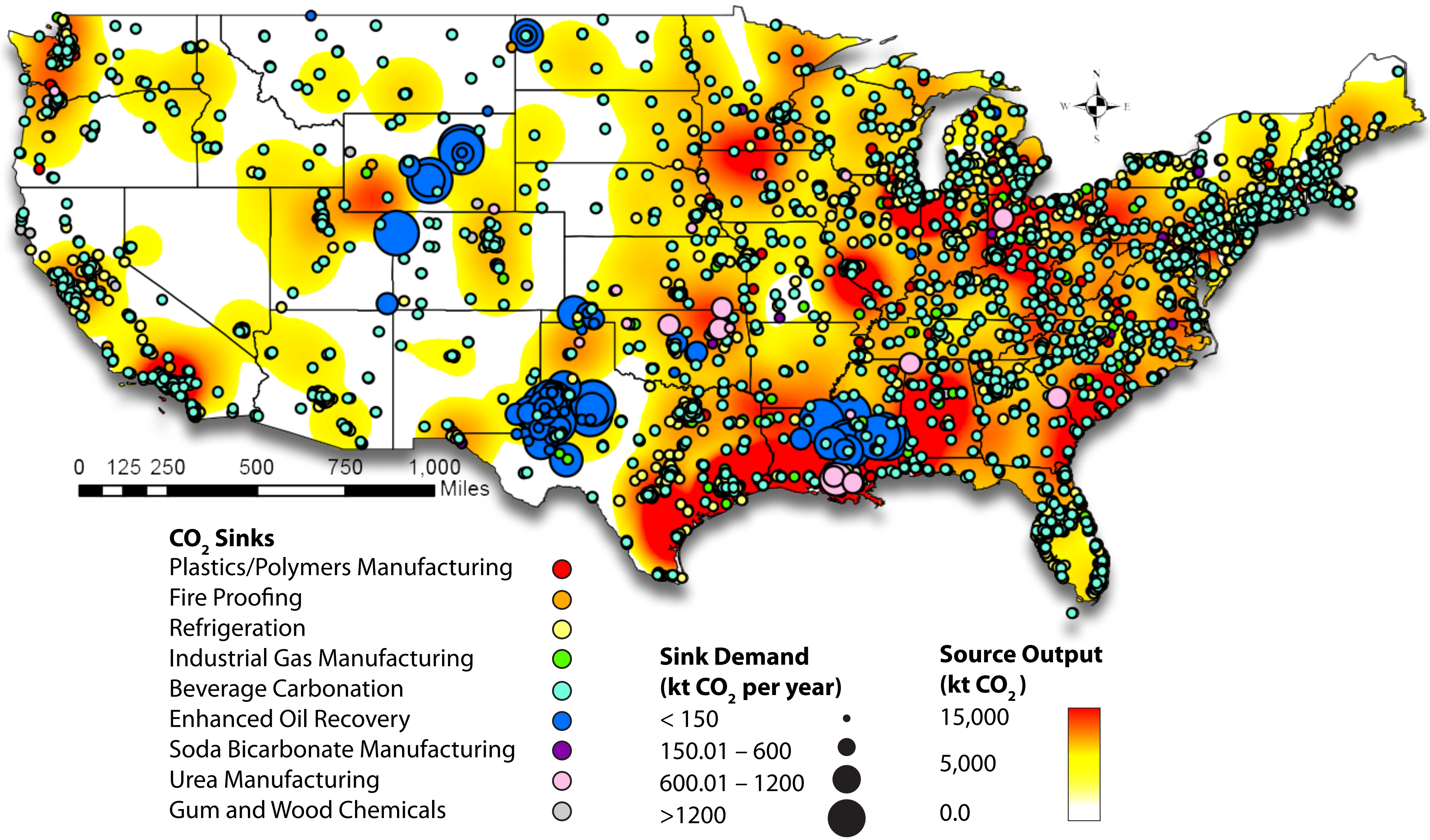
CO_2 sinks – reuse opportunities



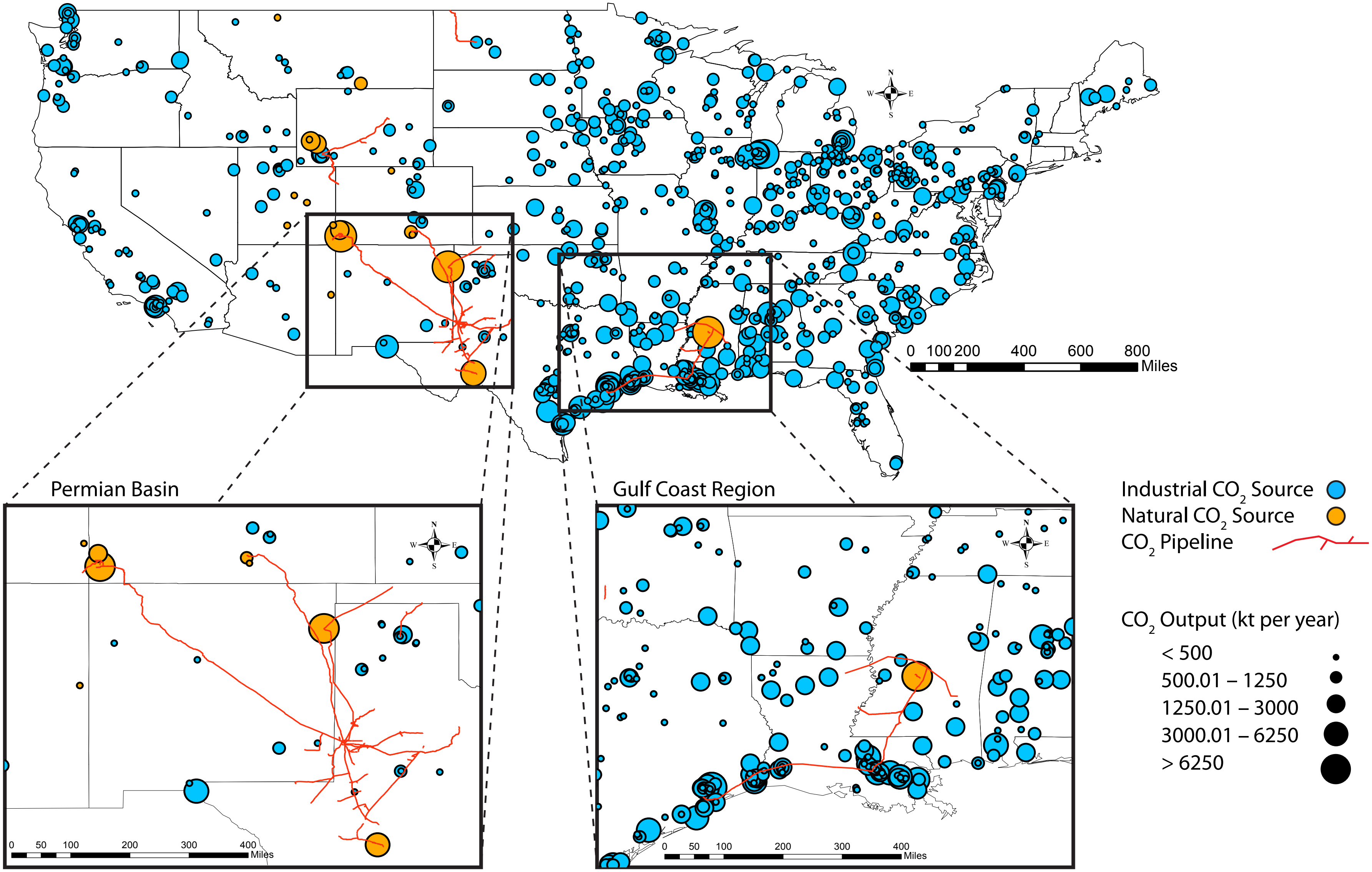
Reference : http://www.netl.doe.gov/research/coal/carbon-storage/research-and-development/co2-utilization

US (Irreplaceable) Industrial Sources of CO_2



Psarras et. al, *A Pathway Toward Removing CO_2 Emissions from the Industrial Sector*, in preparation

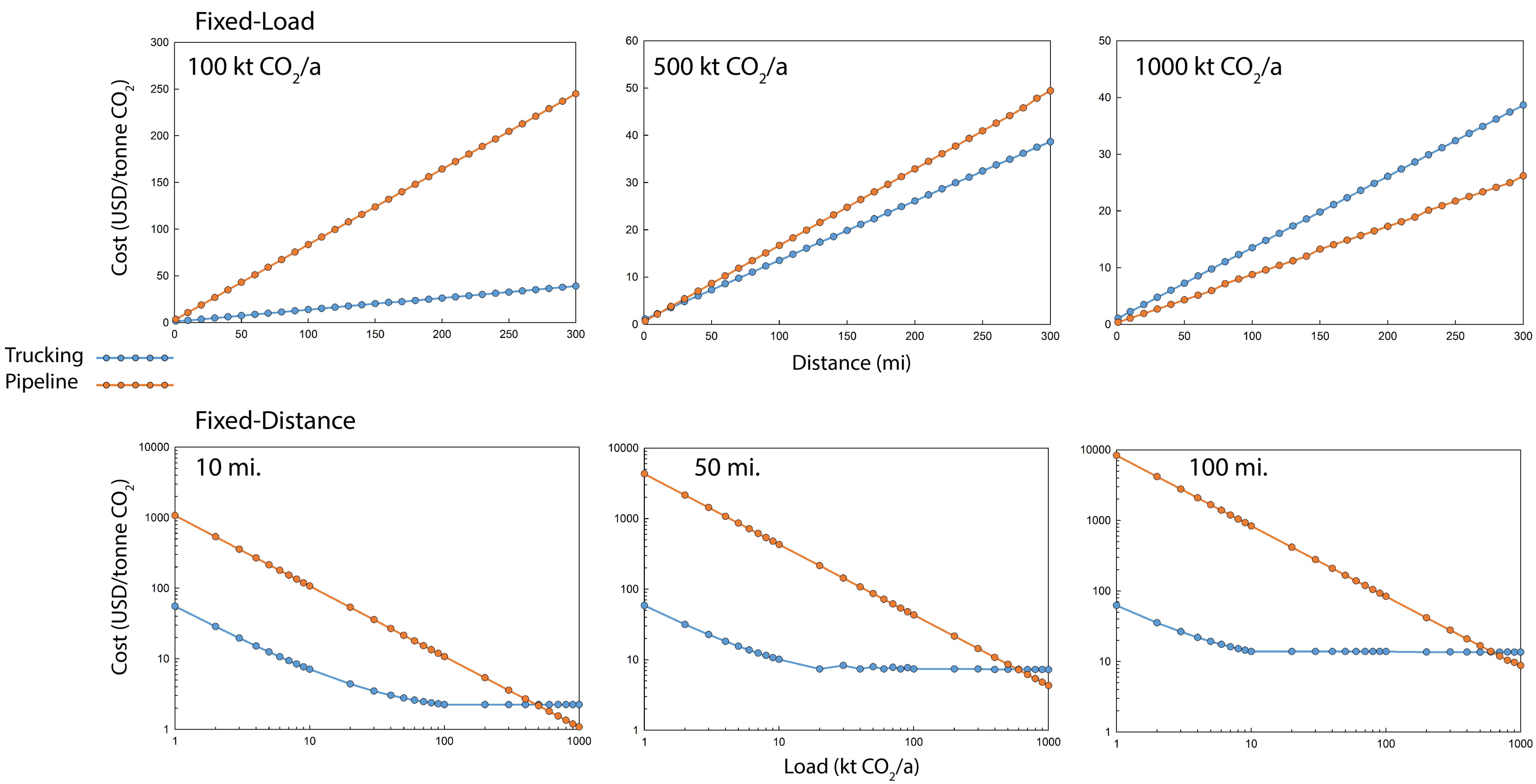
CO_2 Utilization – EOR – Naturally Sourced



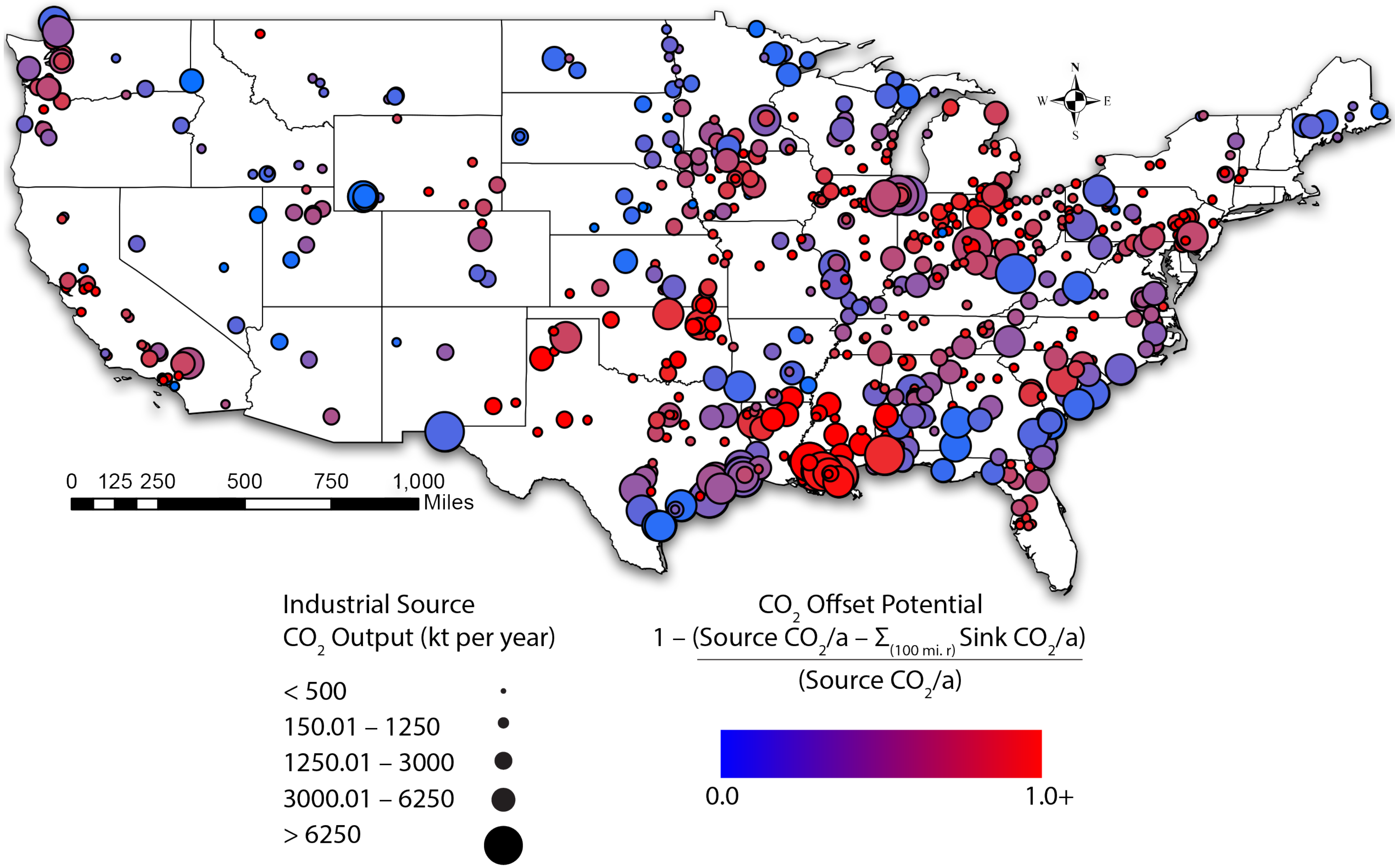
Cost Model: Capture + Compression + Transport

Mode	P (MPa)	T (K)	Compression Power (kWh/tonne)[a]	Cooling Power (kWh/tonne)	Total Power (kWh/tonne)
pipeline	10	308.15	116.4	39.9	156.3
	15	308.15	119.4	39.9	159.2
tanker	1.7	243.15	90.3	16.5	106.8

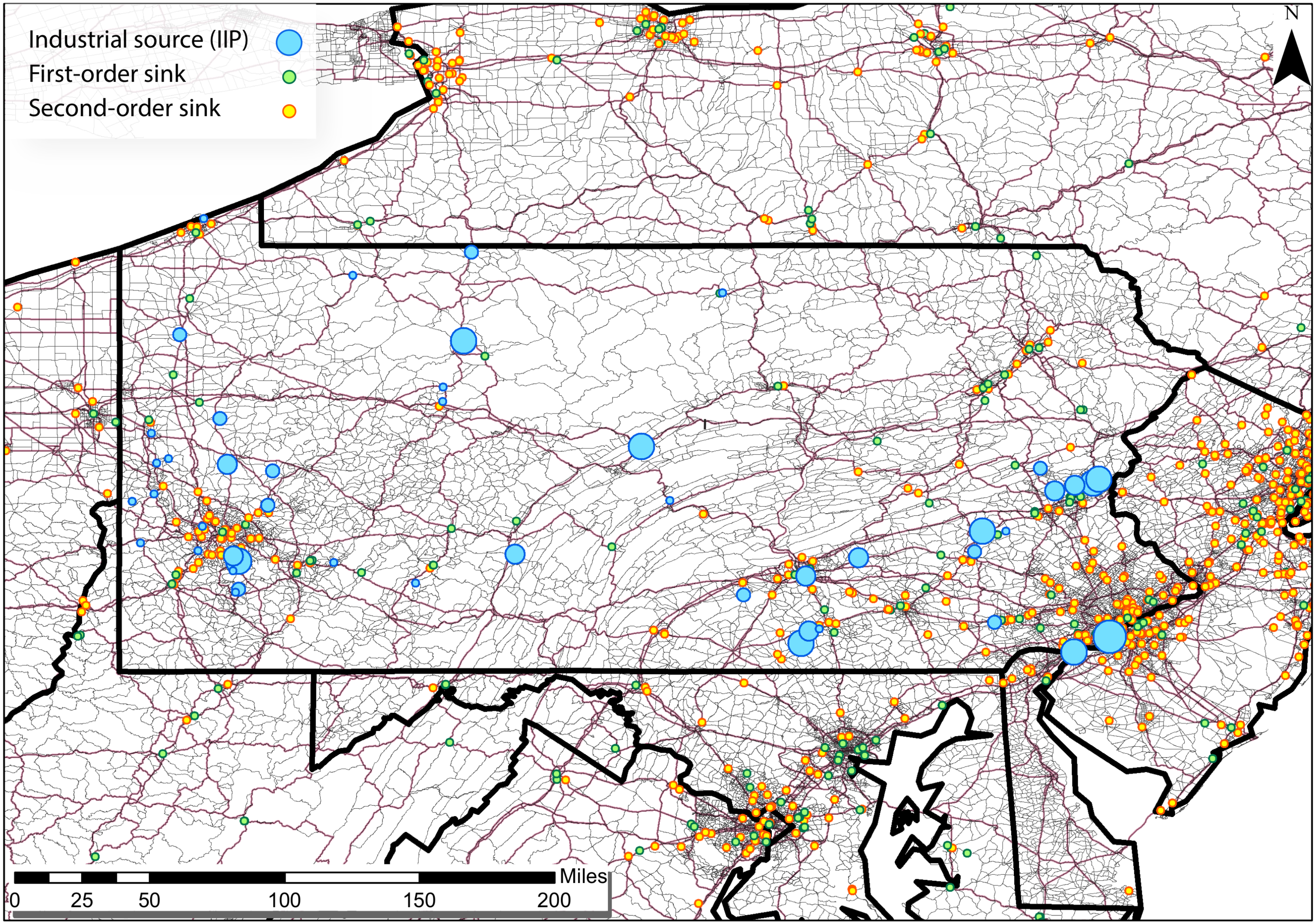
[a] Estimated from compression work calculated per tonne CO_2 generated



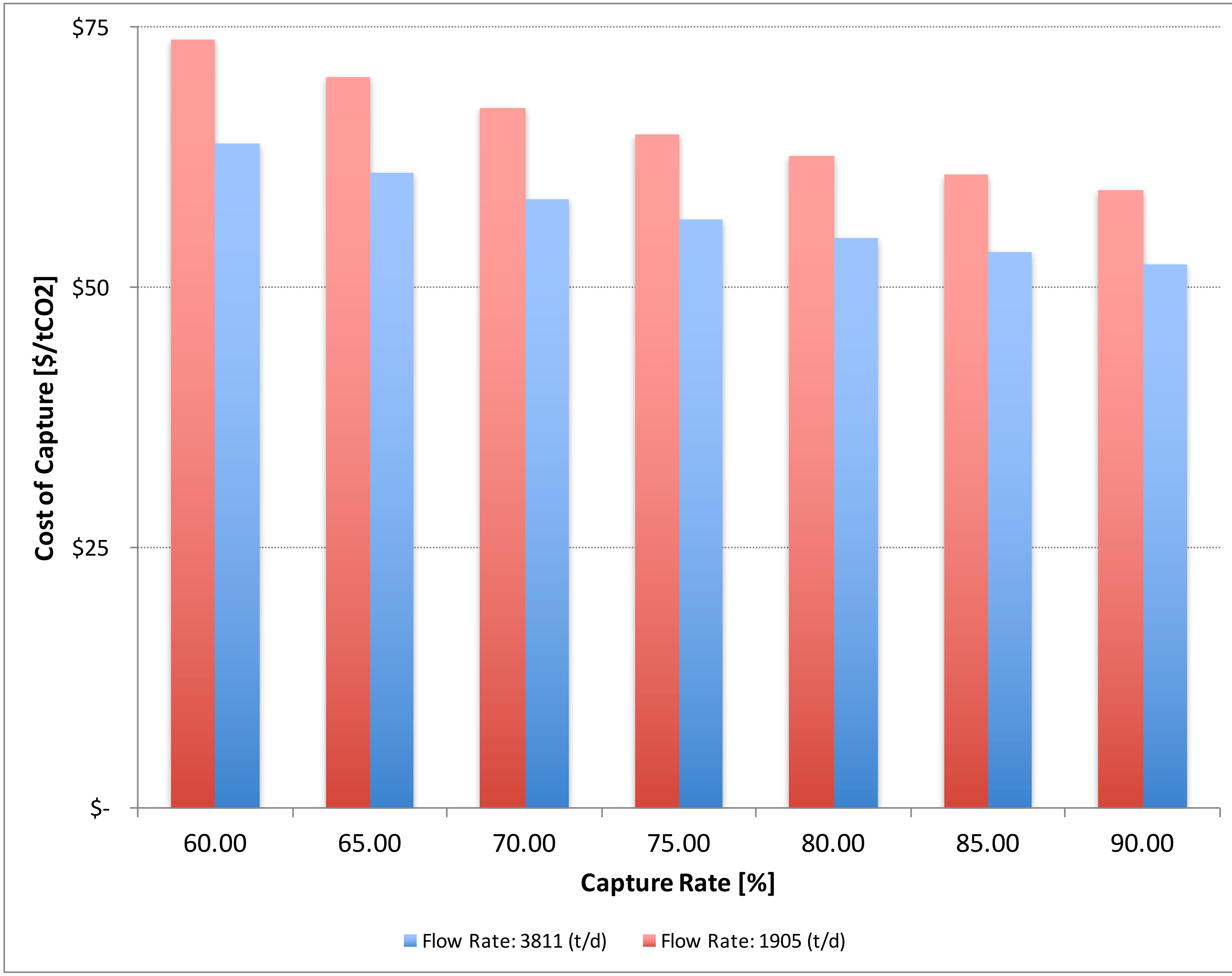
National Level – CO_2 Offset Potential



Regional Level: Pennsylvania



Future Directions – Adjustment to Cost Model



Summary

A pathway forward to carbon neutrality in the Industrial sector should involve

a) Development of a reliable cost-model
b) Identification of "low-hanging fruit" for implementation of capture technologies. Will help to serve as a driver for learning and public acceptance
c) Work to advance **CO_2 reuse opportunities**
d) Work to increase the CO_2 mol % of flue streams via process redesign

Acknowledgements

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Stanford University